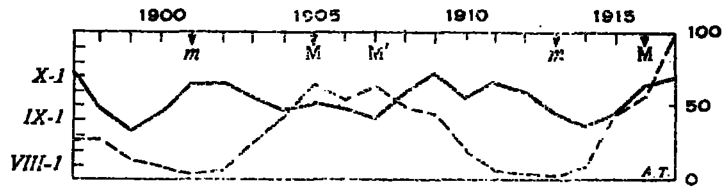

FIG. 3.—Sun-spot numbers and epochs of annual maximum typhoon frequency.

(Broken line=relative annual sun-spot numbers, has been supplied by the editor.)

As for Yang-tze-kiang cyclones, Table 6 is added to point out that there is a general tendency for the annual frequency of cyclones to decrease as the period of sunspot minimum is approached.

TABLE 1.—*Relation between the annual rainfall of Seoul and relative annual sun-spot numbers.*

Annual rainfall.	Relative annual sun-spot numbers.									
	0–20		20–40		40–80		80<		Total.	
	Frequency.	Per cent.	Frequency.	Per cent.	Frequency.	Per cent.	Frequency.	Per cent.	Frequency.	Per cent.
mm.										
<600	2	5	0	0	0	0	0	0	2	1
600–800	8	17	4	14	6	14	5	20	23	16
800–1000	9	19	4	14	9	20	6	24	28	19
1000–1200	11	24	10	34	9	20	4	16	34	24
1200–1400	3	7	4	14	9	20	2	8	18	13
1400–1600	6	14	3	10	4	9	4	16	17	12
1600–1800	3	7	2	7	4	9	1	4	10	7
1800<	4	10	2	7	3	7	3	12	12	8
Total.	46	......	29	......	44	......	25	......	144	......

TABLE 2.—*Relation between relative annual sun-spot numbers and the annual rainfall of Seoul the third year after.*

Rainfall third year after.	Relative annual sun-spot numbers.									
	0–20		20–40		40–80		80<		Total.	
	Frequency.	Per cent.	Frequency.	Per cent.	Frequency.	Per cent.	Frequency.	Per cent.	Frequency.	Per cent.
mm.										
<600	0	0	1	4	1	2	0	0	2	1
600–1000	16	35	12	46	17	36	5	21	50	35
1000–1400	18	41	8	31	18	38	11	46	55	38
1400–1800	7	15	4	16	10	21	7	29	28	20
1800<	5	10	1	4	1	2	1	4	8	6
Total.	46	......	26	......	47	......	24	......	143	......

TABLE 3.—*Deviation of annual rainfall in western Japan from normal, in relation to the epoch of maxima and minima of annual sun-spot numbers.*

Deviation of rainfall.	Year.	Number of years from sun-spot maximum or minimum.		Deviation of rainfall.	Year.	Number of years from sun spot maximum or minimum.	
+35	1905	M	0	−9	1897	M	+4
−23	1904	M	−1	+8	1906	M	+1
−22	1894	M	+1	+8	1912	m	−1
−20	1913	m	0	+8	1914	m	+1
+17	1890	m	+1	−6	1884	M	+1
+15	1915	M	−1	−6	1903	m	+2
+15	1885	M	+2	−5	1892	M	+1
+15	1886	M	+3	−5	1887	m	−2
+12	1889	m	0	−5	1898	m	−3
+11	1901	m	0	+4	1908	M	+3
+11	1902	m	+1	−4	1899	m	−2
+11	1909	M	+4	+3	1896	M	+3
+11	1911	m	−2	−3	1900	m	−1
−11	1889	m	−1	−2	1907	M	+2
−11	1893	m	0	+1	1891	m	+2
−10	1805	M	+2	0	1910	m	−3

TABLE 4.—*Deviation of annual rainfall in western Japan from normal, in relation to the epoch of maxima and minima of annual sun-spot numbers.*

	Absolute values of deviations.					
	0–4	5–9	10–14	≧15	0–10	≧11
Number of cases in which those deviations occurred in the years of sun-spot maxima or minima, or 1 year before or after it	1	5	5	6	6	11
The number of the other cases	6	4	3	2	11	4

TABLE 5.—*Period of annual maximum typhoon frequency.*

Year.	Maximum values of typhoon frequency.	Time of maximum typhoon frequency.		Smoothed time maximum typhoon frequency.	
		Month.	*Decade.*	*Month.*	*Decade.*
1897	1.0	October	First	....	....
1898	1.0	September	Second	September	1.8
1899	1.6	August	Second	August	3.3
1900	1.6	July	Third	September	1.5
1901	1.3	October	Second	September	3.5
1902	1.6	September	Second	September	3.6
1903	2.0	{September {October	Third First	}September	2.6
1904	1.3	August	Second–third	September	1.9
1905	1.6	September	Third	September	2.4
1906	2.7	September	Second	September	2.0
1907	1.6	August	Second	September	1.3
1908	2.0	September	Third	September	3.0
1909	1.6	October	Second	October	1.5
1910	1.3	September	Third	September	2.8
1911	2.0	{September {October	Third First	}September	3.8
1912	1.6	September	Third	September	3.1
1913	2.3	September	First	September	1.6
1914	1.6	August	Second–third	August	3.8
1915	2.3	September	First	September	1.6
1916	1.6	September	Third	September	3.4
1917	1.0	October	First–second	....	....

TABLE 6.—*Annual frequency of Yang-tze-kiang cyclones.*

Year.	1904	1905 (M)	1906	1907	1908	1909	1910	1911	1912	1913 (*m*)	1914	1915	1916	1917 (M)
Number of cyclones	15	15	8	13	9	7	7	9	4	9	10	13	10	11

CUMULUS CLOUDS OF HAWAII.

By ANDREW M. HAMRICK, Meteorologist.

[Dated: Cheyenne, Wyo., June 23, 1918.]

The cumulus clouds of Hawaii, especially those which pile up over the Koolau Mountains on the Island of Oahu, are so remarkable in their method of formation that a brief description of them may be interesting in connection with the Bureau's renewed activities in the observation of clouds and upper-air conditions.

They are not convection-formed clouds in the sense of warm air rising and expanding to maintain atmospheric equilibrium, but are the result of the moist air being *forced* upward by the prevailing Northeast Trades as they strike against the steep sides of the Koolau Mountain range. This range extends throughout the length of the Island of Oahu, and lies at right angles to the direction of the Trade winds; therefore the only course of the latter is up, and over.

As the Trade winds prevail throughout the year, the huge cloud-cap may be observed both night and day, summer and winter, except occasionally when overpowered by the "Kona" storms. The height and extent of the clouds usually depend upon the strength of the wind.

References have been made by meteorologists to the fact that cumulus clouds are often convection-formed over islands, by the air over the ground warming more rapidly during the day than that over the oceans. I am sure this plays no important part in the formation of the clouds on Oahu because of the following reasons: (1) The mountain range closely parallels the northeastern coast of the Island, and as it is nearly always shaded by the cloud-cap the ground does not have an opportunity to warm sufficiently to cause an uprising current of air. (2) The "cloud-rack" does not disappear as night comes on, but remains unchanged in appearance so long as the Trade winds blow with sufficient velocity to force the air over the top. The fact that the greater part of Honolulu's precipitation occurs during the night hours further substantiates these statements. (3) The Island of Oahu is so narrow that a land and sea breeze is seldom, if ever, experienced thereon, and surely not at Honolulu.

for the lowering of the dew-point 0.33° for every 300 feet of increase of elevation, on account of expansion, we find that the moisture should condense and the cloud begin to form at about 2040 feet: $\frac{75°-65°}{1.47} \times 300 = 2040$. This is what really happens, for the base of the cumulus cloud rack usually rests on the mountain peaks at about 2,000 or 2,200 feet above sea level, although on warm days, which seldom have a temperature above 90°F., it may be at the top of the highest peak, Konahuanui, elevation, 3,100 feet.

The upper part of figure 2 shows Konahuanui (extreme left) cloud-capped, while the range to the right is below the cloud base. This photograph was taken on a warm day. The lower part of figure 2 shows the same range to the right well within the clouds, and the patches of sunshine and shadow at the base clearly show that the

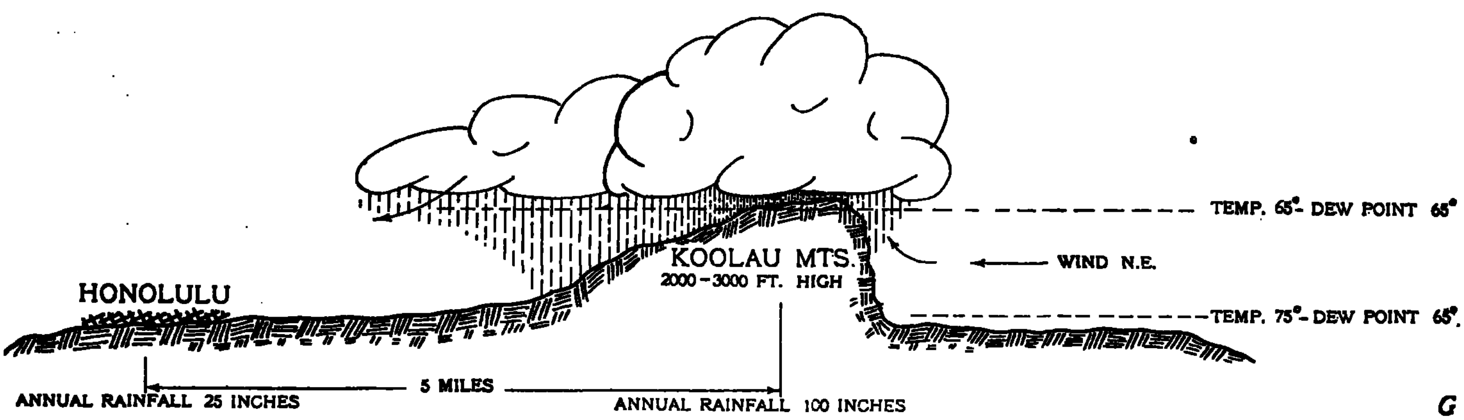

FIG. 1.—Cross section of the Island of Oahu and the cloud-cap over Koolau Mountains.

The accompanying diagram and photographs (figs. 1 to 3) in addition to showing the method of cloud formation, clearly illustrate the fact that were Oahu a low, level Island it would be but a barren desert. By a fortunate coincidence the mountain range lies in the proper direction, and it is of sufficient elevation, to cooperate with the steady Northeast Trades in extracting a bountiful supply of moisture from the heavy-laden atmosphere. This, in a measure, is true of the other large Islands of the group; although they do not all possess mountain ranges, there are points upon them ranging from 3,000 to 13,800 feet elevation above sea level. These obstruct the passage of the moisture-laden Trades, and collect sufficient water to feed constantly the irrigation ditches, upon which the greater part of the agriculture in the Hawaiian Islands depends. The smaller low-lying islands of the group are unproductive because of lack of rainfall.

Figure 1 illustrates the reasons for such large differences in the annual rainfall within very short distances. For instance, in the business district of Honolulu the average annual rainfall is about 25 inches, while 3 miles northeast of the city, or about halfway to the summit of the mountains, it is 100 inches per annum.

The Koolau Range averages from 2,000 to 3,000 feet high, and this seems to be the proper elevation, under the existing atmospheric conditions, to obtain the maximum cloud formation. From three daily sets of observations made at the top and the base of the "Pali" (precipice), (see X, X in upper part of fig. 2), the average temperature decrease was found to be 1°F. for every 165 feet of ascent. With a temperature at the base of the "Pali" of 75°, and dew-point 65°, and allowing

weather is not so ominous as a first glance would indicate. See also the upper part of figure 3, taken from the *leeward* side, looking into the wind.

With a 10 or 20 mile trade wind at the base of the range it sometimes whips over the tops of the mountains at a terrific rate, and this velocity is a determining factor in blowing the top of the "cloud-rack" far enough over to cause rain in Honolulu, even though the sun is shining brightly on that city. (See fig. 1.) Such showers are locally termed *"liquid sunshine"* and are a great source of interest to the "malihini" (stranger).

The lower part of figure 3 is a familiar view from Honolulu, and to a person entering the harbor for the first time it is a beautiful, though threatening, outlook. It appears as though a terrific thunderstorm, less than five miles away, were about to break upon him—but it never does. With the "cloud-rack" blown a little closer, the *Promise* (rainbow) comes with it, so there is no fear. The small boy in Honolulu has long since lost faith in the story of the "pot of gold at the end of the rainbow," for he has looked in *the very spot* too many times. The nearest to the "pot of gold" are the rich sugar-cane and pineapple plantations. Because of the peculiar natural setting, there is probably no place else in the world where rainbows are more often seen than in Honolulu. This is true of lunar as well as solar rainbows, for similar conditions prevail at night, and the tropical full moon brings out the colors of the rainbow in all their splendor.

Because of the excessive moisture from the cumulus clouds, vegetation in the mountains is dense and rank, impenetrable except where trails are cut.

Aviators have soared over the cloud-cap at elevations of from 8,000 to 9,000 feet, and this coincides with my

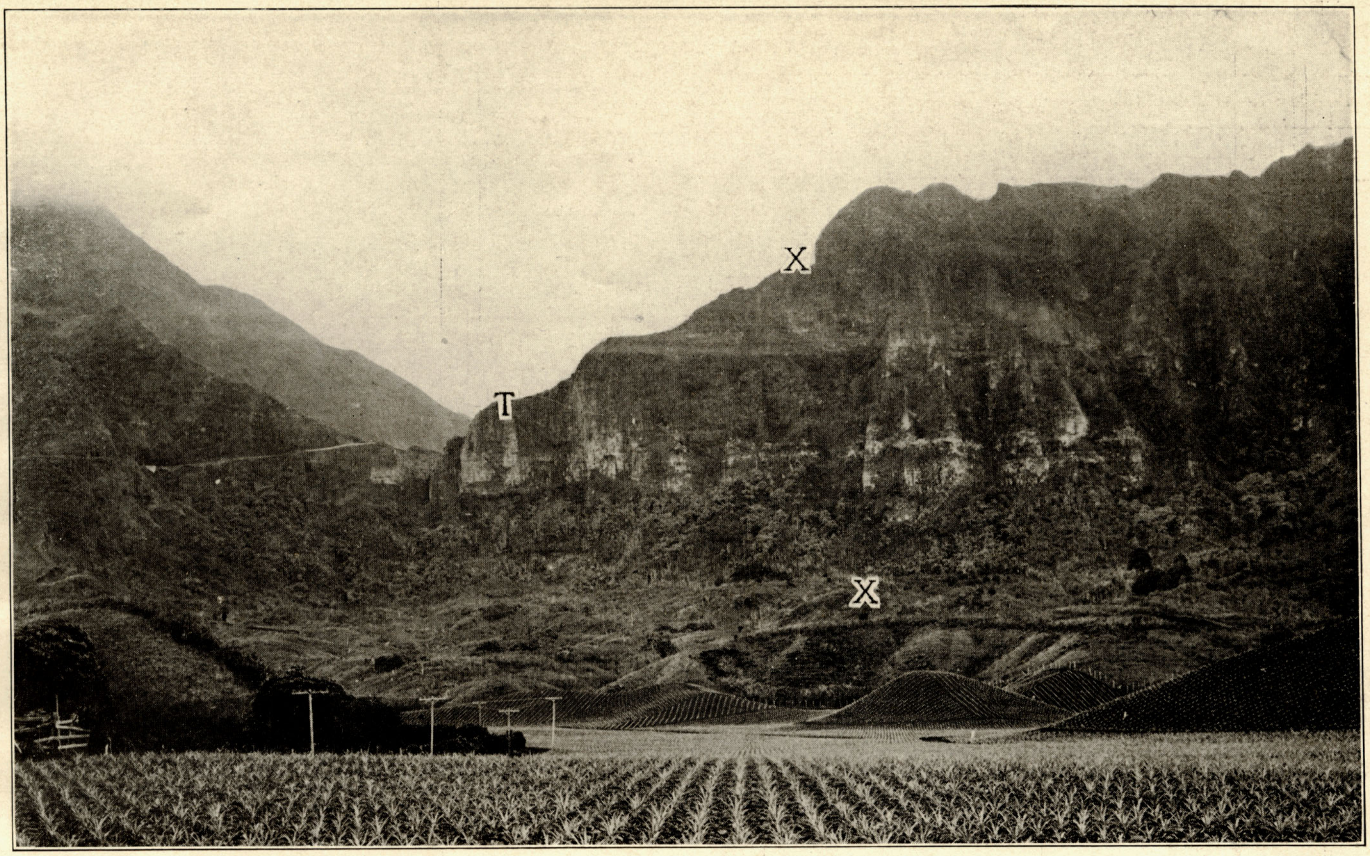

FIG. 2.—(*Upper*) Koolau Mountains, Konahuanui, cloud-capped, is on the extreme left. In the center, crosses (x, x) show points where half-hourly observations of temperature, humidity, and cloud movement were made. At point marked (T) an anemometer was installed, and it registered 60 miles of wind an hour for 5 hours; (*lower*) Cloud-cap on Koolau Mountains from windward side. (Wind from northeast.)

FIG. 3.—(*Upper*) Cloud-cap on Koolau Mountains from leeward side, looking northeast. Taken halfway up to "Pali" from Honolulu; (*lower*) Cloud-cap on Koolau Mountains from Honolulu, looking northeast.

estimates from rough measurements that the depth of the cloud from top of dome to base is from 3,000 to 5,000 feet.

NOTE.—The type of cloud described in the foregoing article has been named *crest-cloud* by W. J. Humphreys, who says, in his "Physics of the Air" (Jour. Frankl. Inst., May. 1918, p. 635):

The crest cloud is formed by the upward deflection of the wind by a long mountain ridge. It usually covers the higher slopes as well as the top, and though called cloud by people in the valleys below, is likely to be designated fog by any one actually in it. Occasionally condensation occurs only along the upper reaches of the deflected winds, in which case the cloud belt is above and to the leeward of the mountain ridge.

In either case the individual droplets are quickly evaporated and the cloud form preserved only through continuous condensation from renewed air. It is permanent in the same sense that a cataract is permanent through the continuous supply of water by the stream above.

Identical in mode of origin with the crest-cloud is the *cap-cloud* or *cloud-cap*, formed over an isolated peak. These clouds, due to the forced ascent, of moist air over mountains, were once known as *parasitic clouds*—a term introduced by Marcellin du Carla in his memoir "Sur les nuages parasites" (Rozier, Observations sur la physique, etc., v. 24, 1784, p. 392–399; 456–473; v. 25, 1784, p. 31–38; 94–102). This author describes the occurrence of the clouds in question in various parts of the world and endeavors to explain them as due to condensation in an updraft of air caused by the emission of subterranean heat from mountains. In the Annales de la Société d'agriculture de Lyon, v. 2, 1839, there is an account of a cloud of this type as observed on the summit of Mont Pilat, south of Lyons. ("Note sur le développement d'un nuage parasite au Pilat.") In his book on "The Mediterranean" (London, 1854), p. 235, Admiral W. H. Smyth says that during the development of the solano at Cadiz "parasitic clouds, as they are termed by meteorologists, cap the hills of Medina Sidonia."

Of the more important local examples of such clouds it is necessary to mention here only the Helm Cloud of the English Lake District, and the Table Cloth of Table Mountain, South Africa; both famous in meteorological literature.

An excellent specimen of the crest-cloud is the so-called *foehn-wall* (*Föhnmauer*), seen along the crest of an Alpine ridge over which a foehn is blowing. This is described and illustrated in Dr. F. Kerner von Marilaun's paper "Die Föhnmauer" (Ztschr.Deutsch. u. Oesterr. Alpenvereines, v. 23, 1892).—*C F. Talman.*

SOME NEW FACTS ABOUT THE CENTERS OF TYPHOONS.

By CO-CHING CHU.

[Dated: Cambridge, Mass., June 15, 1918.]

TEMPERATURE CONDITIONS IN THE CENTER OF A TYPHOON.

No problem connected with the study of tropical cyclones is more interesting and more vital than that which concerns the "eye" of the storm. The "eye" is the central region of relative or absolute calm. The calm may last a few minutes, or more than an hour. Immediately after the period of calm, the wind at once regains its strength, and blows with hurricane force from a direction nearly or exactly opposite to that from which it came before the calm. Some years ago, Sidney M. Ballou made an investigation of the phenomenon of the eye of the storm.[1] He gave several authoritative accounts of the phenomenon as observed before 1892, and suggested the probable explanations for its existence. Since then, however, many additional accounts of the eye of the storm have found their way into the reports of the different observatories and meteorological services, and a complete analysis of these would doubtless throw much more light on the subject. The present paper can deal with only a few of the accounts which have been given in the Monthly Bulletins of the Philippines Weather Bureau during the years 1904–1915. We will discuss first the temperature conditions in the center of a typhoon.

It is to be regretted that readings of the thermometers are not always given in the reports of the phenomena associated with the passage of the eye of the storm. A knowledge of the temperature condition in the eye is necessary in order to understand many other phenomena, like the clearing of the sky, etc, which are related to the passage of the calm center.

Regarding the temperature condition of the atmosphere during the passage of the central calm in the famous Manila typhoon of October 18, 1882, Father Algué says:[2]

When at noon on the 20th of October, 1882, Manila entered the central part of the vortex, the absolute calm, the temperature suddenly rose during its passage from 25°C. (77°F.) to 31.5°C. (88.7°F.), but fell again to its former level after the center had passed the city. This is a change which is exceptional, for no such rise was noticed either on the 5th of November, 1882, at Manila, or, as far as we know, on any other occasion. It, therefore, attacted the attention of meteorologists, and gave rise to various controversies, in which each one took the example to support his own view. Faye also made use of this change of temperature to prove the existence of descending air currents in the interior of cyclones.

After a close examination of all the circumstances we will find that the temperature remained steady and comparatively low from 7 p. m. on the 19th till a little before the transit of the center—that is to say, during the time in which the rain squalls were almost incessant and the gusts of wind freshened until they reached the force of a cyclonic storm. This steady, low temperature is without any doubt to be ascribed to the showers and wind squalls. According to the regular oscillations of temperature on cloudy days, the thermometers had to fall during the afternoon of October 19, since during that month the normal temperature for 7 p. m. does not reach 26°C. (78.8°F.). After that hour the temperature decreases very slowly to 24°C. (75.2°F.) at midnight, and then remains fairly constant until 7 a. m. It is, therefore, nothing extraordinary if, from 7 p. m. of October 19 to 7 a. m. of October 20, the temperature remained slightly below 25°C. (77°F.). Usually, indeed, on cloudy days the thermometer rises between 7 a. m. and noon to 27°C. (80.6°F.), but during these hours on October 20 the winds were already more than brisk, the squalls frequent, the rain heavy and continually increasing until the entrance into the relative central calm. At this moment the dense covering of the nimbus grew lighter, the squalls ceased, the wind calmed down, the sky became almost clear; Manila was within the extended region of vortical calm of about 14–16 miles diameter. What wonder, then, that without any other cause but solar activity from a sky nearly clear, by simple radiation, the temperature rose rapidly till it reached the normal height, which is 31.5°C. (88.7°F.) for a cloudless day in October?

Discussing the same subject, Hann says:[3]

Merkliche Änderungen der Temperatur und Feuchtigkeit im Zentrum einer Zyklone werden nur bei jener vom 20. Oktober, 1882, zu Manila angegeben, wo die Temperatur auffallend stieg und die relative Feuchtigkeit abnahm. Bisher ist kein gleicher Fall berichtet worden.

During the years 1904–1915 at least four cases of an increase of temperature during the passage of the central calm of typhoons have been found. Indeed, in one case the rise of temperature was more remarkable than even that during the celebrated Manila storm of 1882. This occurred on September 16, 1912, at Taito, Formosa. Between 8 and 9 p. m. of the 16th, the minimum reading

[1] *Sidney M. Ballou*, "The Eye of the Storm." American Meteorological Journal 1892, 9:67–82, 121–127.
[2] *Algué*, "Cyclones of the Far East," p. 63.
[3] "Lehrbuch der Meteorologie," Leipzig, 1915, p. 596.